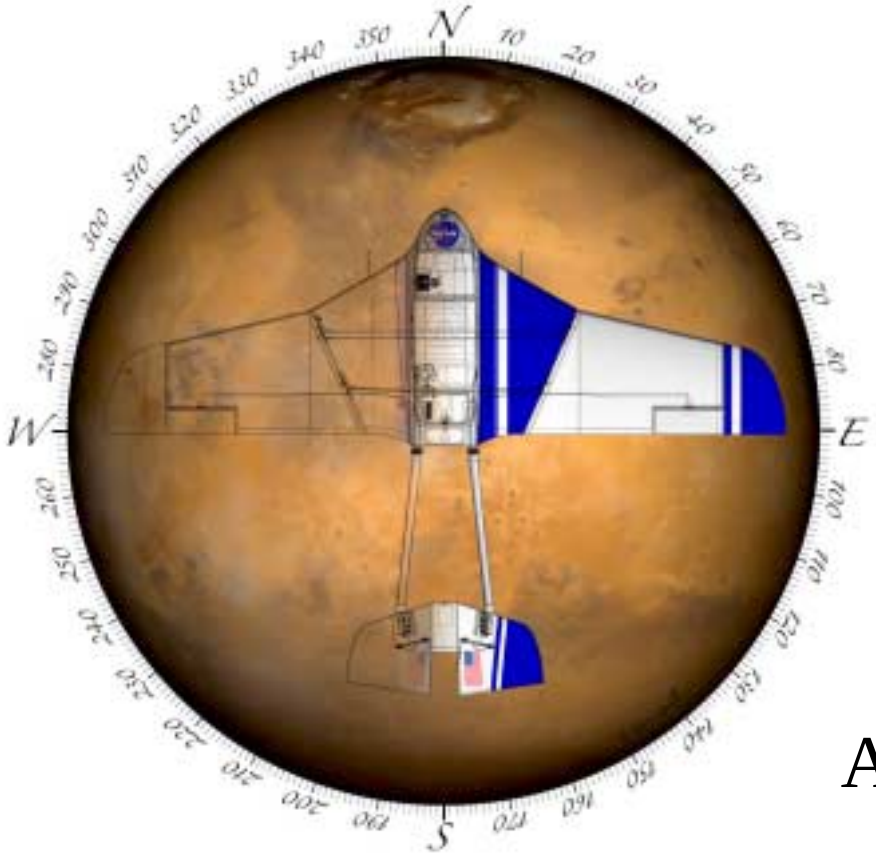


MARS AIRPLANE

Mark Croom

AirSC Technical Talk Series

Sept 22, 2004

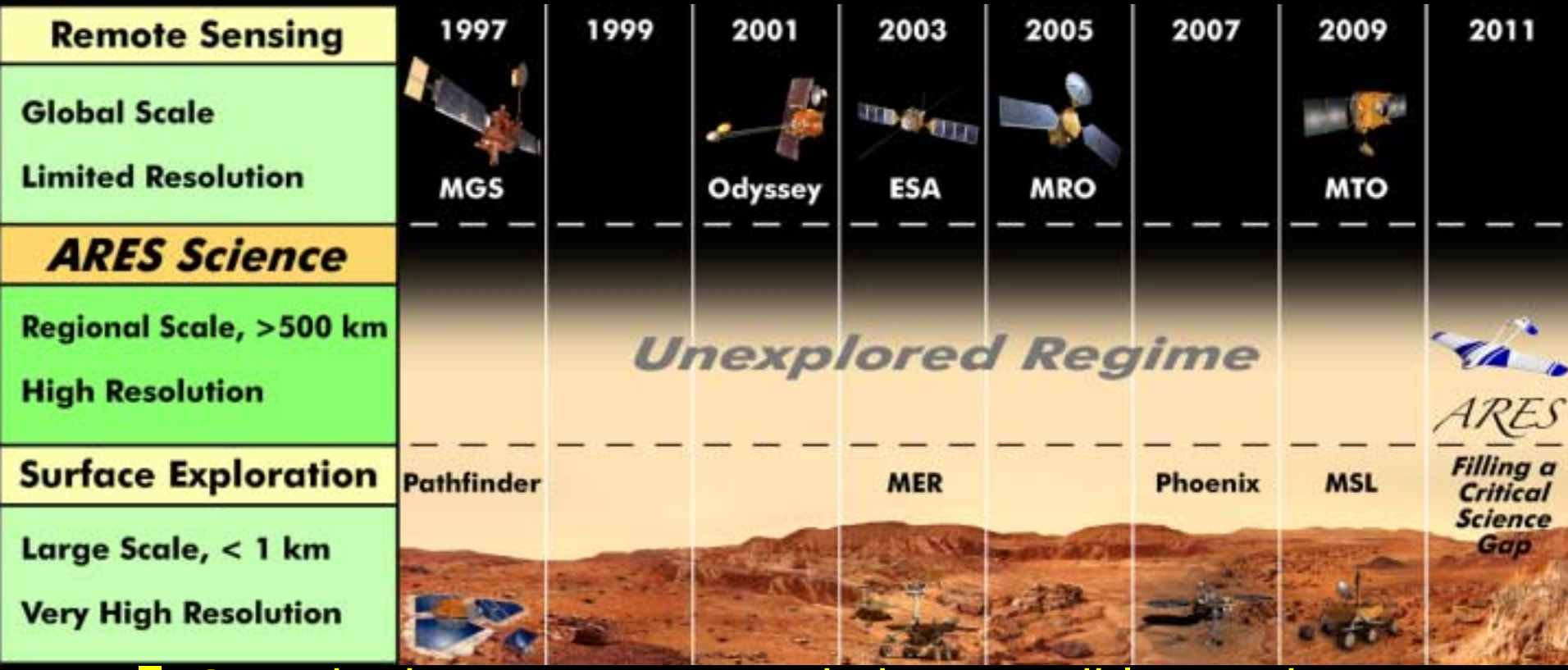
ARES

Aerial Regional-scale Environmental Survey

Mars Scout Opportunity

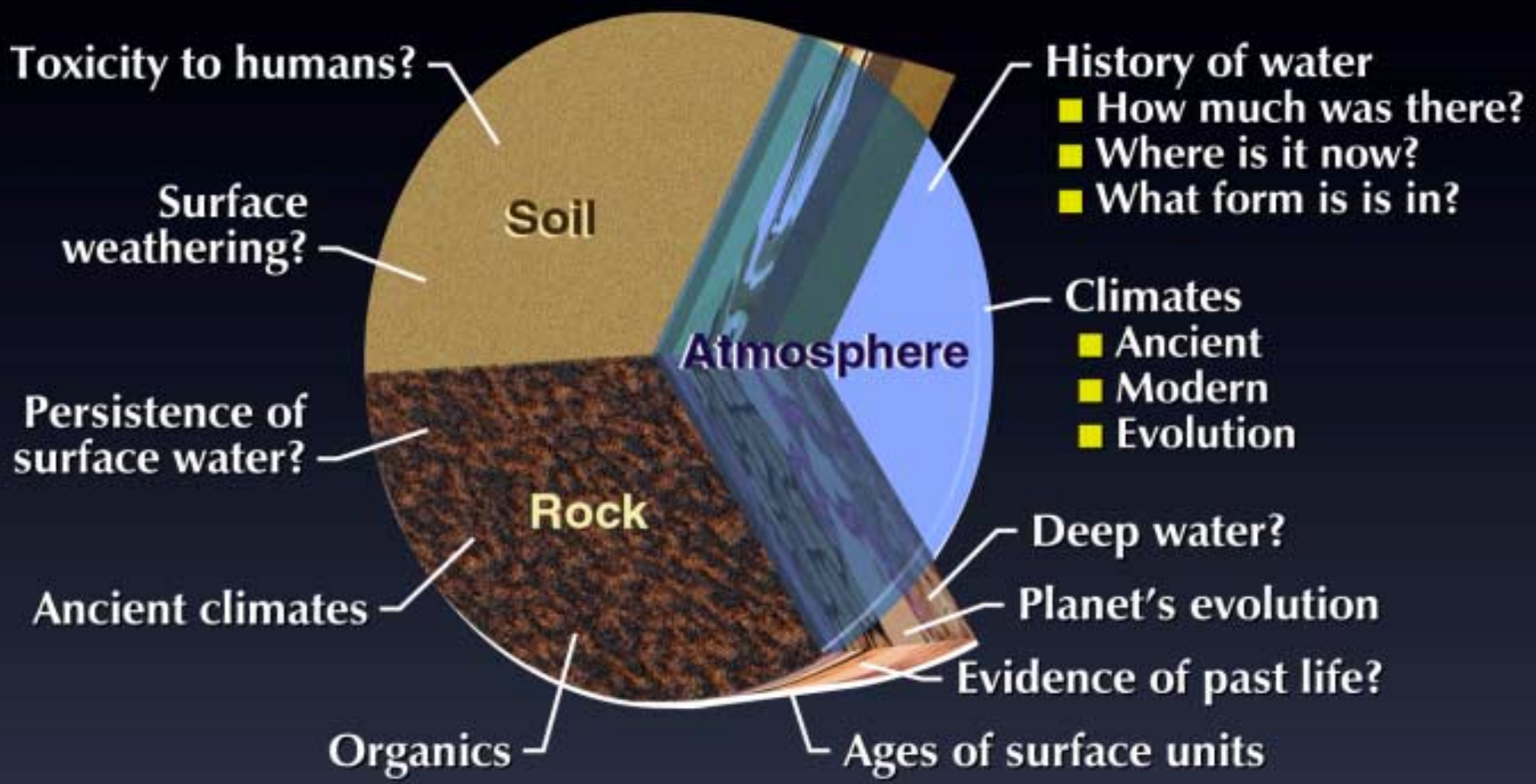
- Innovative, rapid response investigations which complement baseline core missions of the Mars Exploration Program
- Science focused, Principal Investigator Led
- Missions cost-capped at $325M (FY03 dollars)
- Two Step Proposal Process
  - Step 1 AO release 05-2002
  - Step 1 Proposal due date 08-2002
  - Step 1 Selections 12-2002
  - Step 2 Proposal due date 05-2003
  - Step 2 Selected Phoenix 08-2003
- Launch date as early as mid-2007

Unique Advantages of an Airplane



- Can obtain measurements in inaccessible terrain
- Can cover vast distances across the planet
- Can be guided to sites of particular scientific interest

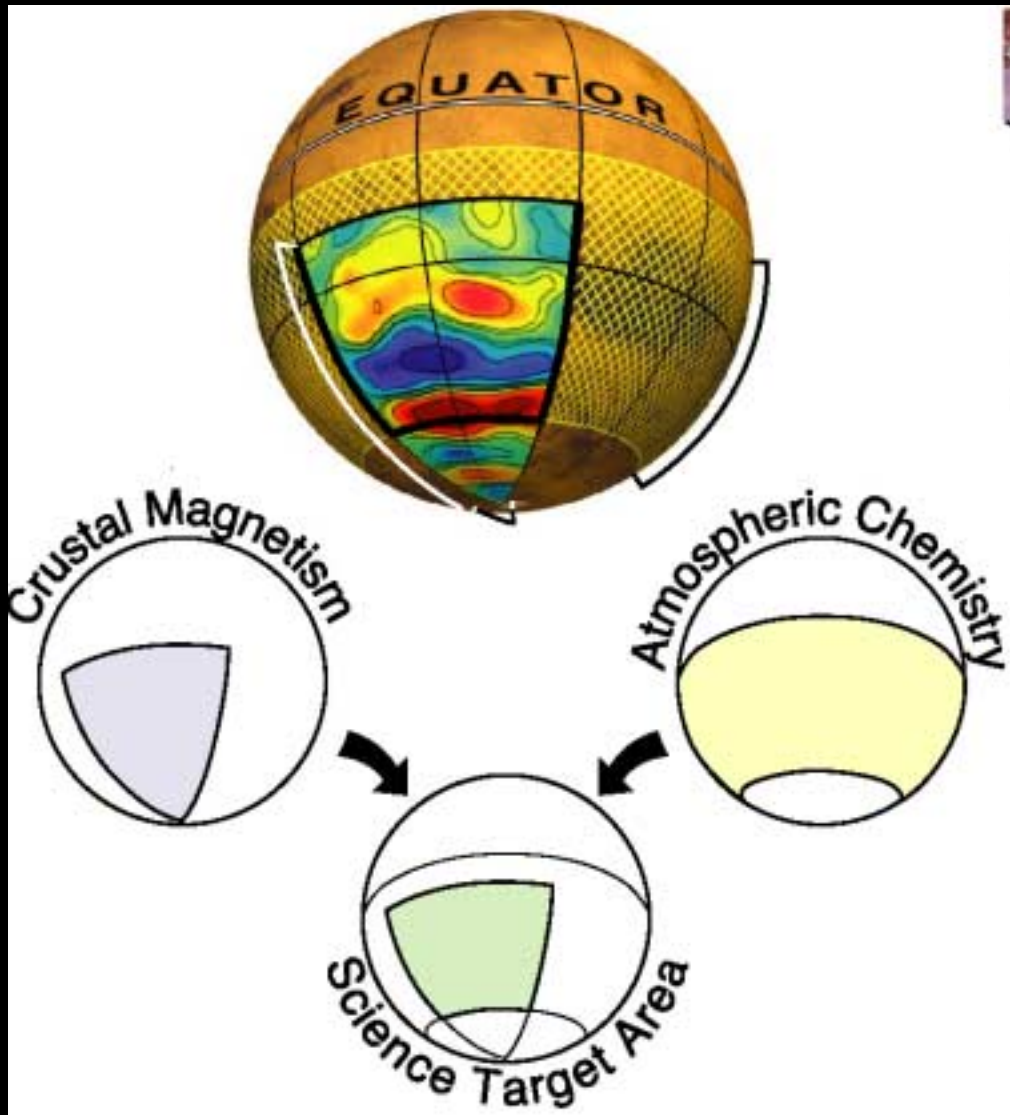
What We Can Learn About Mars

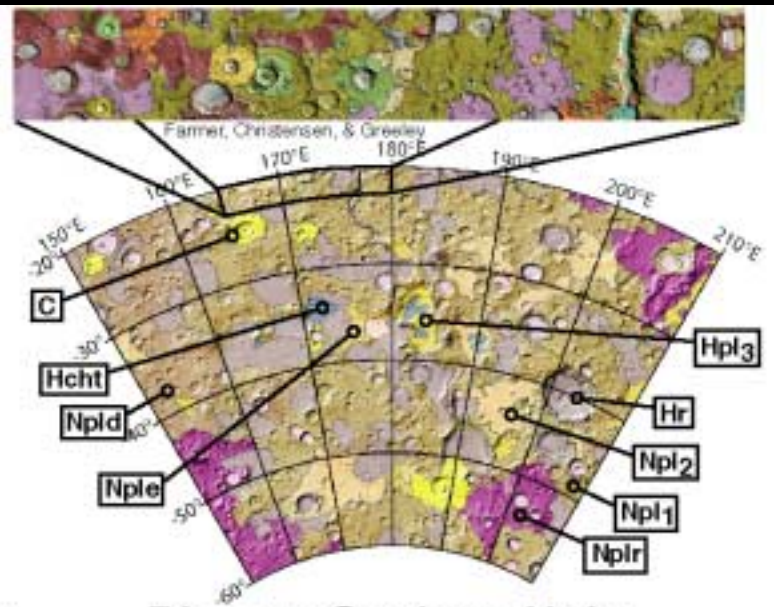


ARES Science is Category 1

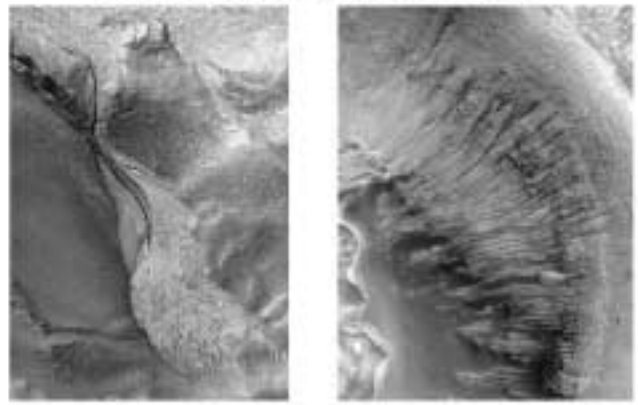
- Study crustal magnetism via aero-magnetic survey
  - Correlate with surface spectra
  - Correlate with imagery
- Study atmospheric gases within the first scale-height
  - In-situ' mass spectrometer measurements
  - Correlate with imagery
- Characterize local atmospheric states
  - Ancillary science goal
  - Natural consequence of flight GN&C requirements
- Perform regional scale science investigations on Mars

ARES Science Target Area



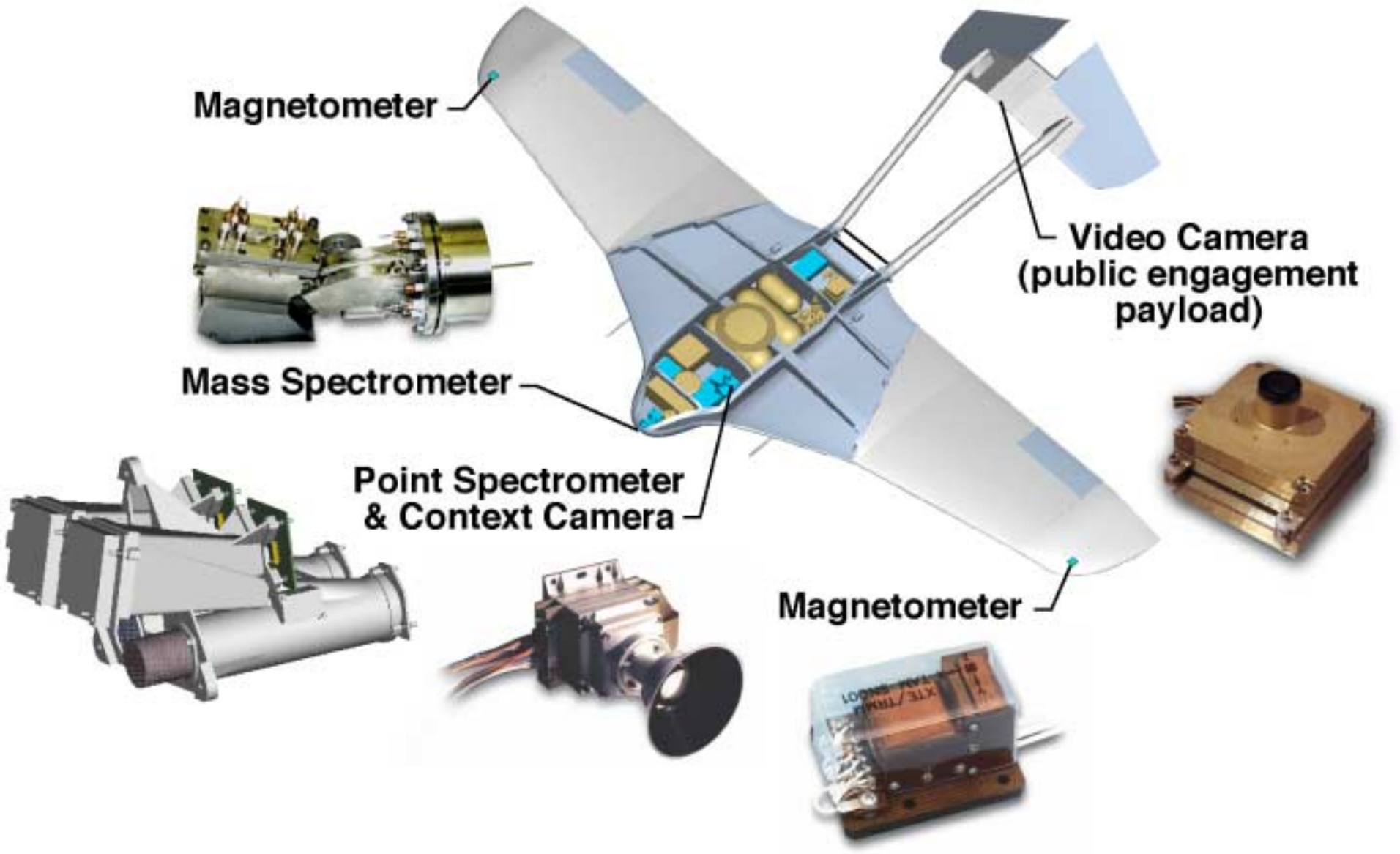


Diverse Geology Units and Ancient Terrain

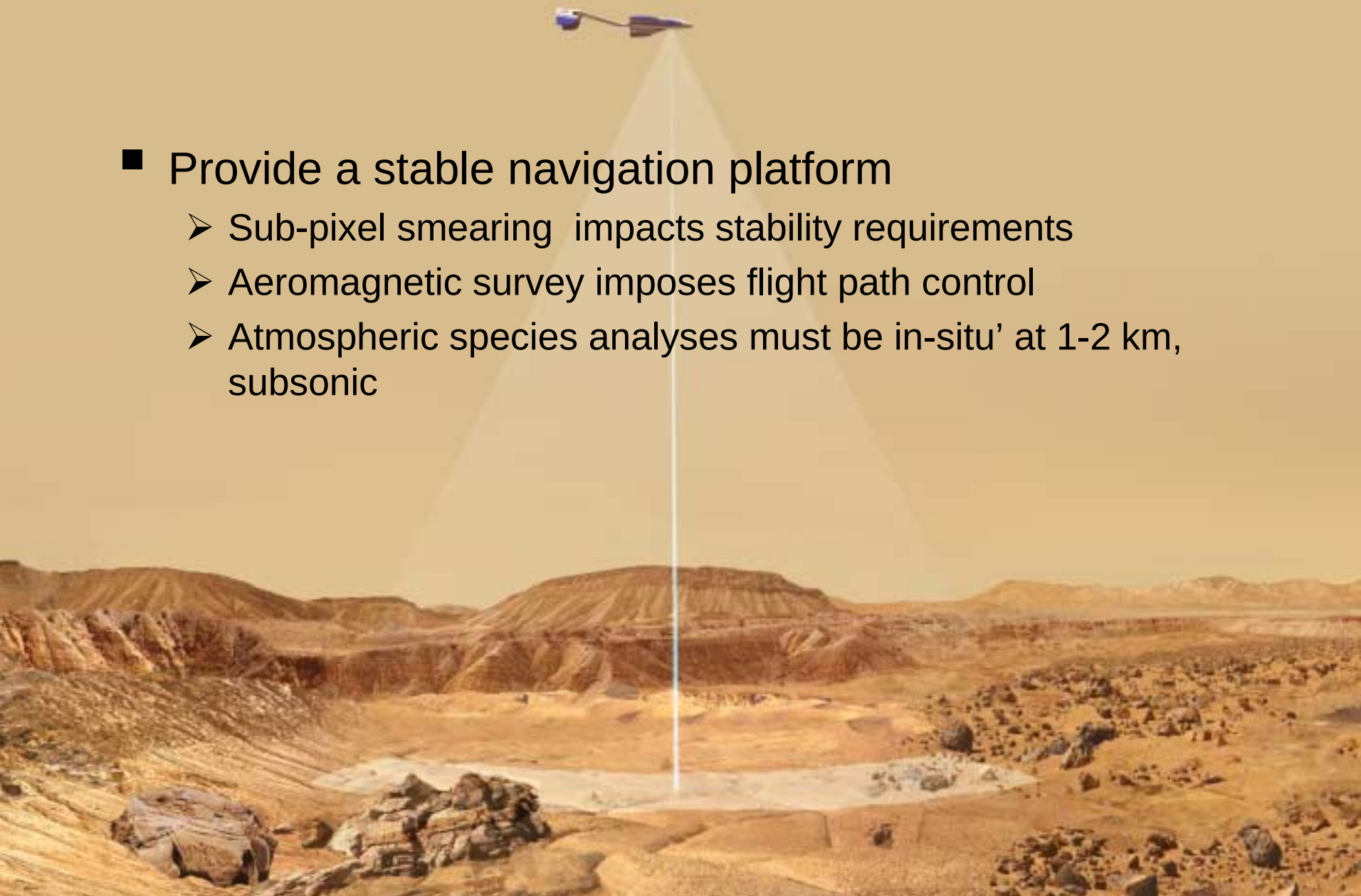


Potential Surface Water Sites

Science Instruments

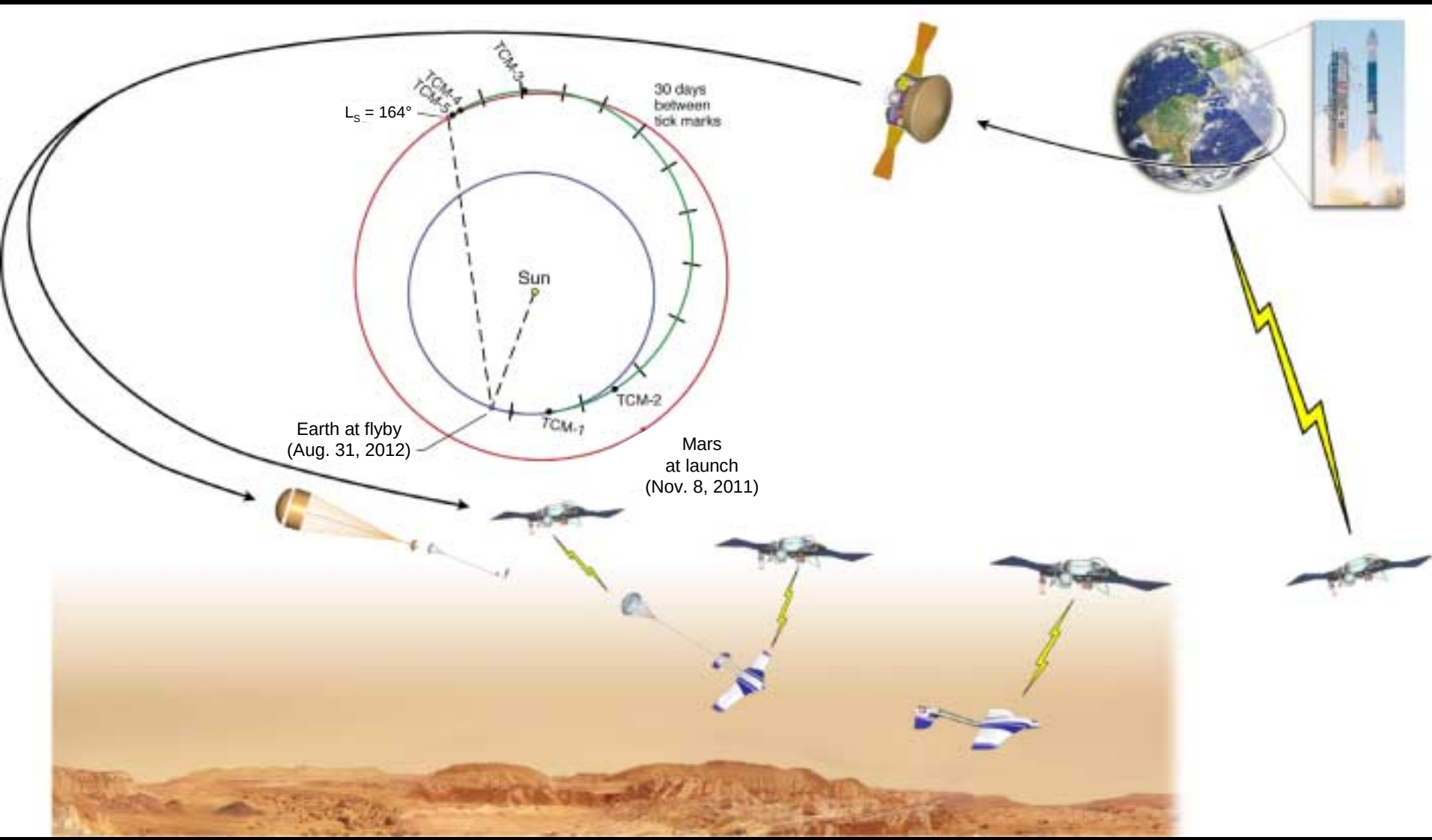


Science-Driven Requirements

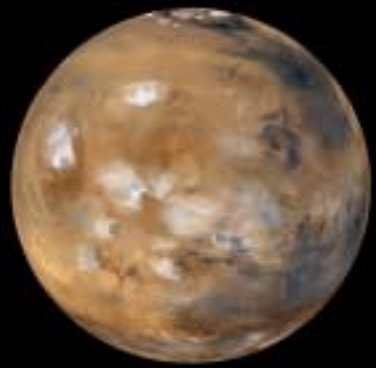


- Provide a stable navigation platform
  - Sub-pixel smearing impacts stability requirements
  - Aeromagnetic survey imposes flight path control
  - Atmospheric species analyses must be in-situ' at 1-2 km, subsonic

Mission Description



Earth-Mars Comparison



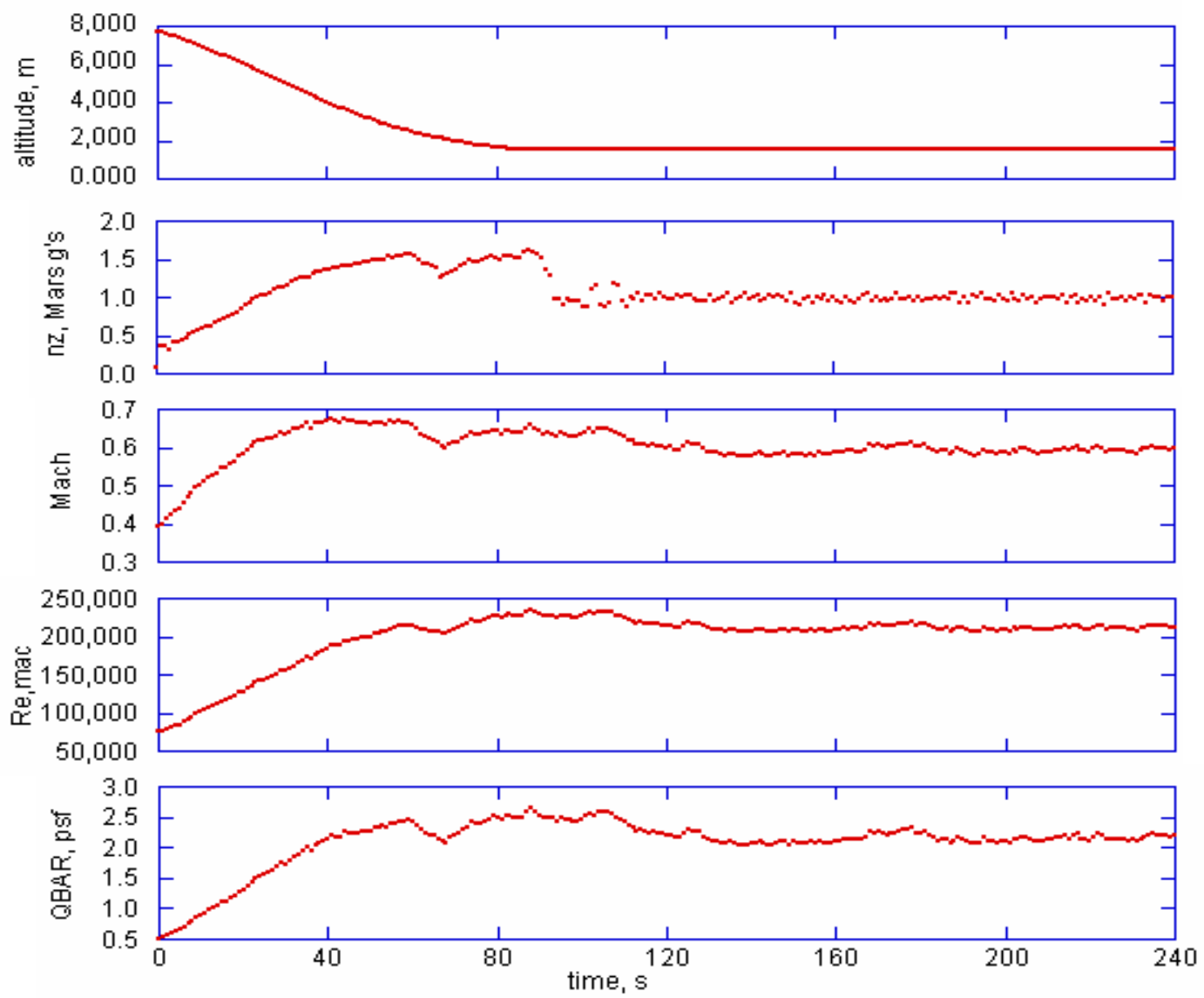
Diameter = 7920 miles
Gravity = 1 g
Surface Pressure = 1000 mbars
Topographic Variability = 12 miles
Atmos. = 79% N_2; 21% O_2
Global Magnetic Field

Diameter = 4220 miles
Gravity = 0.38 g
Surface Pressure = 6.4 mbars
Topographical Variability = 18 miles
Atmos. = 95.3% CO_2; 2.7% N_2;1.6% Ar
Localized Magnetically Active Regions

What's Hard About Flying on Mars?

- Environment
  - *Density 1/100th of Earth*
  - *Speed of sound 2/3 of Earth*
  - *Temperature 100°F Colder*
- Autonomous operation
  - *Round trip radio time – 6 – 44 minutes*
  - *Event sequencing*
  - *No GPS or compass*
- Uncertainty
  - *Know starting point within a few miles*
  - *Winds*
  - *Flight altitude vs. local topography*

Sample Initial Flight Segment



Design Considerations

- Getting there
  - Must survive launch plus ~1 year in space
  - Must be packaged in protective entry body and then transition to an airplane
- Fly fast!
  - Need to fly below speed of sound to keep drag in check
  - But need to fly as fast as possible to generate lift
- Custom design
  - Airfoils
  - Unfolding
  - Dependable, credible (esp. aero & propulsion)
  - Flight Controls
- Keep it Simple

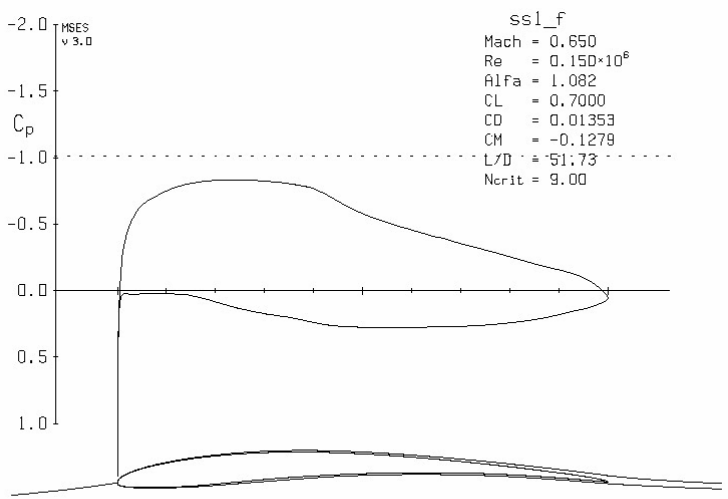
Airplane Team

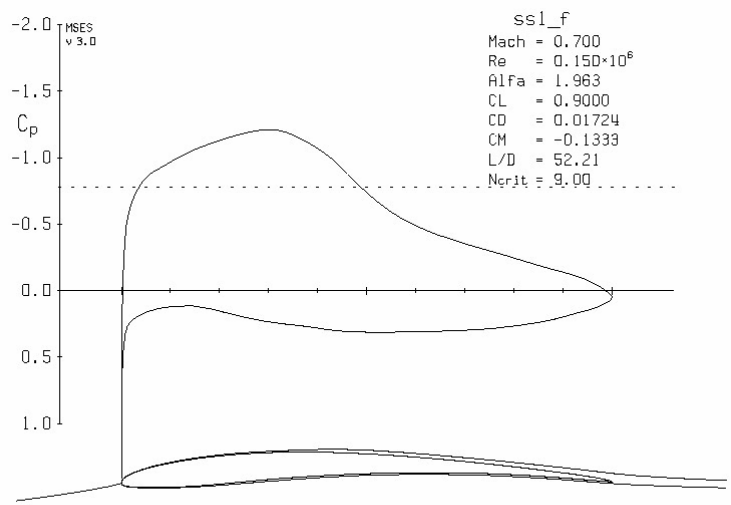
- Mars Airplane/Airplane Team
  - Crucial element of the overall ARES project structure
  - Multi-disciplinary
    - Aero, GN&C, Structures, Propulsion, Thermal, Manufacturing, Telecon, Subsystems, Planetary Protection, ATLO, …
  - National team
    - NASA: LaRC, ARC, DFRC, GRC, JPL
    - Academia: MIT, Stanford, GWU
    - Industry: Aurora, Draper, Lockheed, subsystem providers
- Multi-faceted design process
  - Relatively simple platform design
  - Must meet unusual mission-based requirements
  - Accommodate mission elements throughout mission maturation process
  - Puts / takes to mission architecture

Speed	325 MPH
Endurance	60-90 Min.
Range	300-400 Miles
Empty Wt.	280 lbs.
Fuel Wt.	106 lbs.

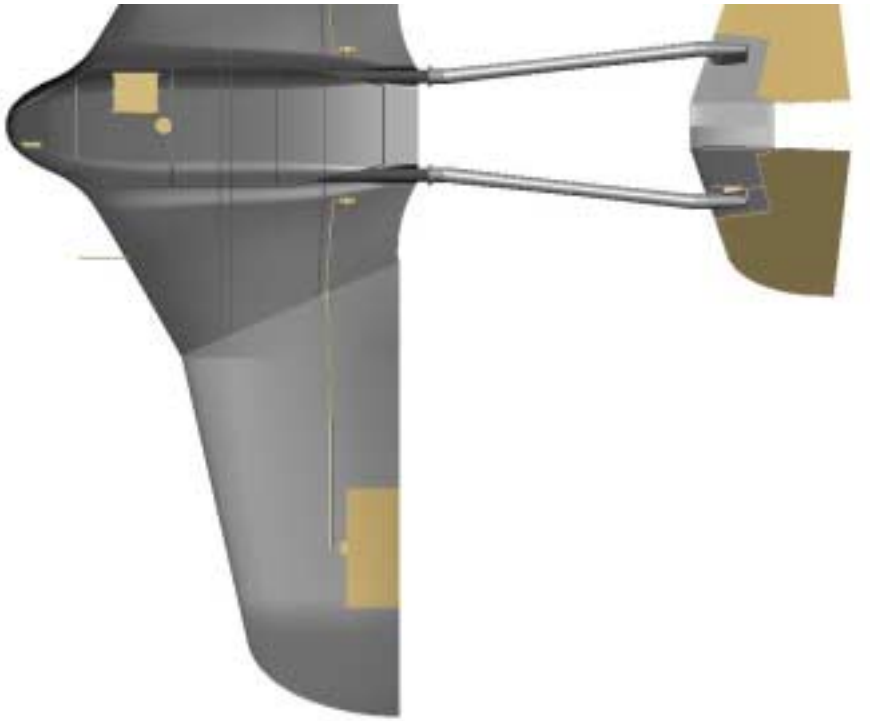
Airfoil Design Methods

- **Limited database at Re=150,000, Mach 0.7**
- **MSES v.3.0 2-D Euler + coupled Integral B.L.**
  - industry “Standard” for transonic design
  - some low-Re applications
- **Validate with 2-D RANS, WT test**



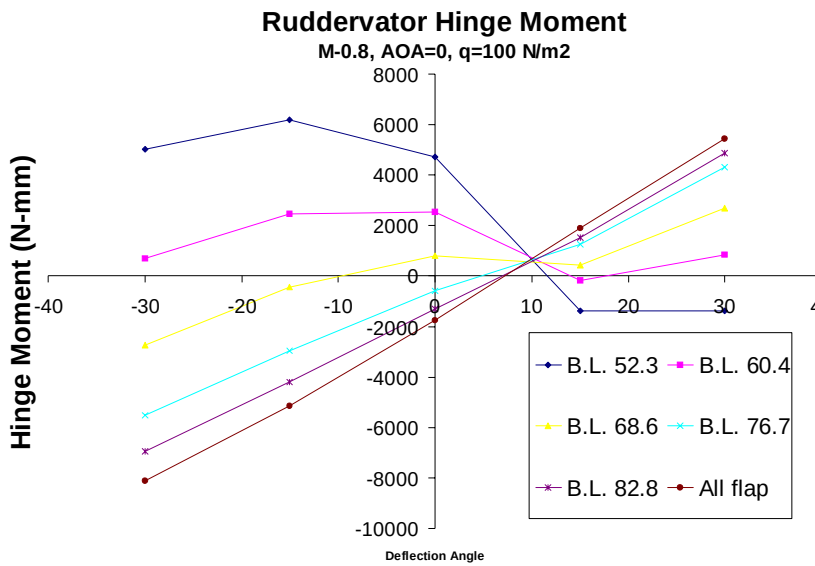


Control Surfaces

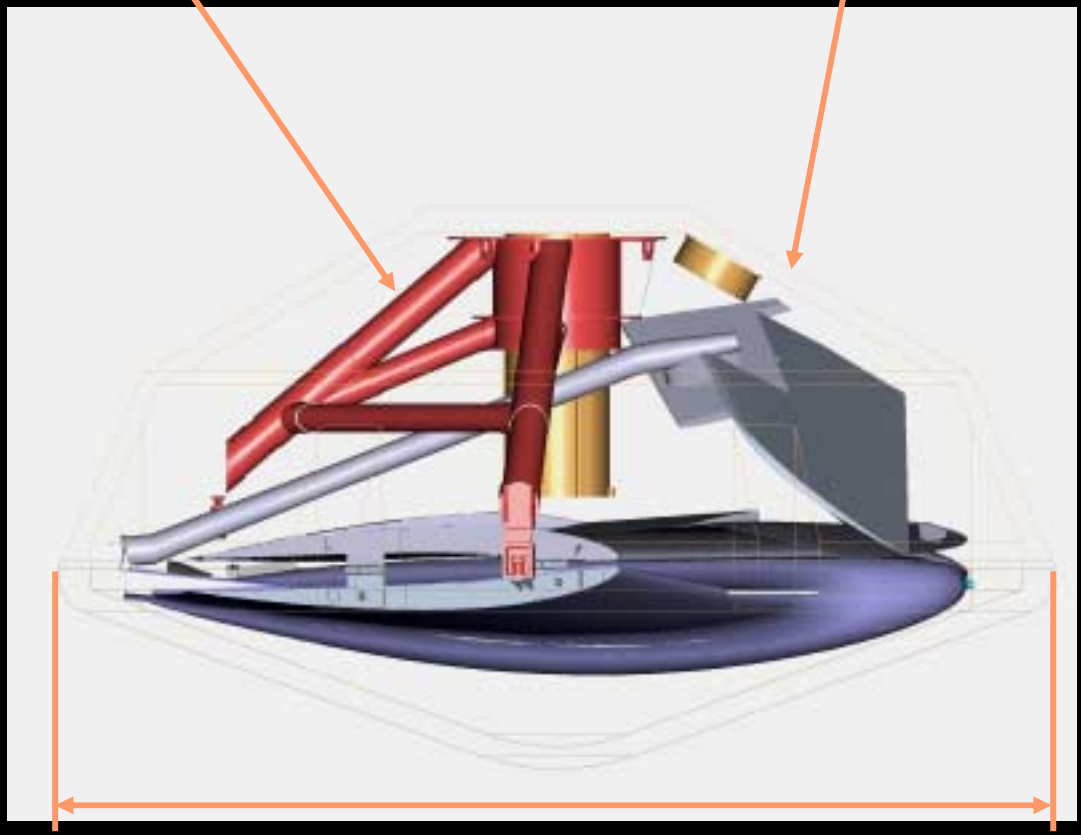


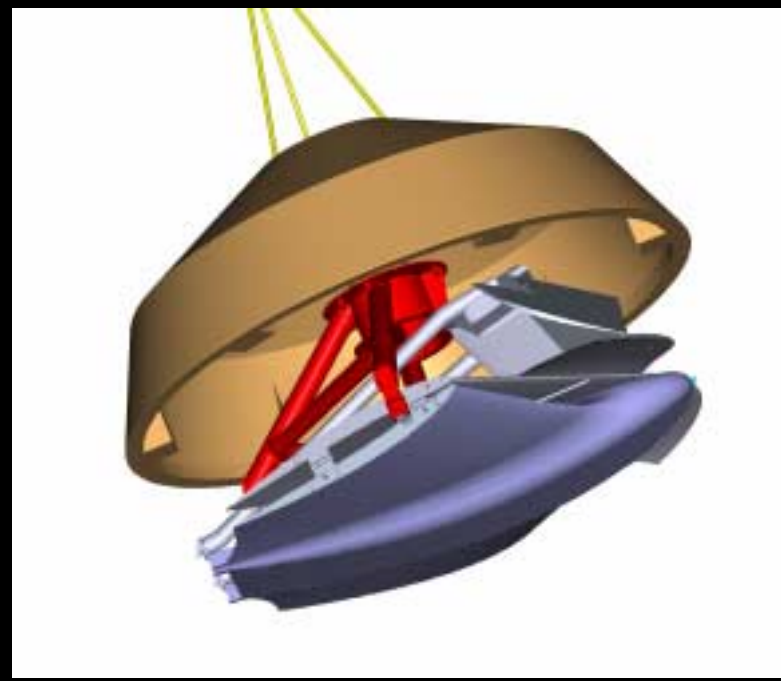
- Control utilization
  - Ailerons
    - Differential for roll
    - Symmetric for pull-out lift enhancement
  - Ruddervators
    - Pitch and yaw
    - Extreme deflection for stowage

- Control design
  - Performance, S&C, maneuvering
  - Packaging
  - Load / torque management
  - Simplicity / redundancy



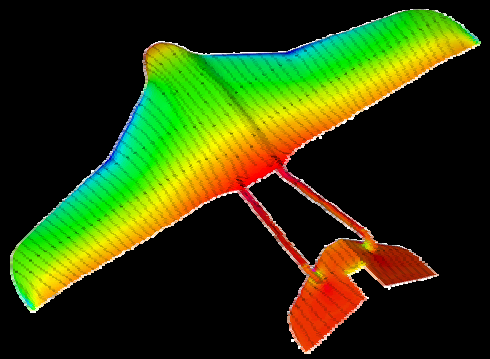
Packing for the Long Trip



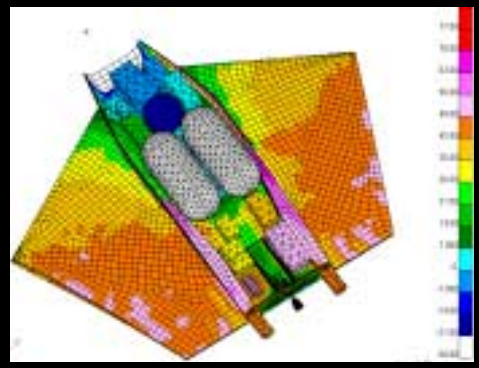


Airplane Just Prior
to Release

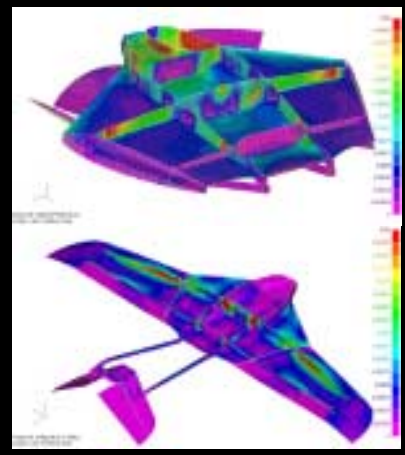
Concept Credibility: Simulations and Testing



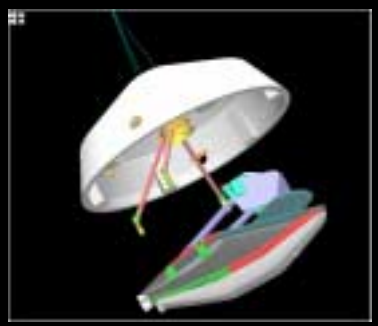
Aerodynamic Simulations



Thermal Simulations



Structural Simulations



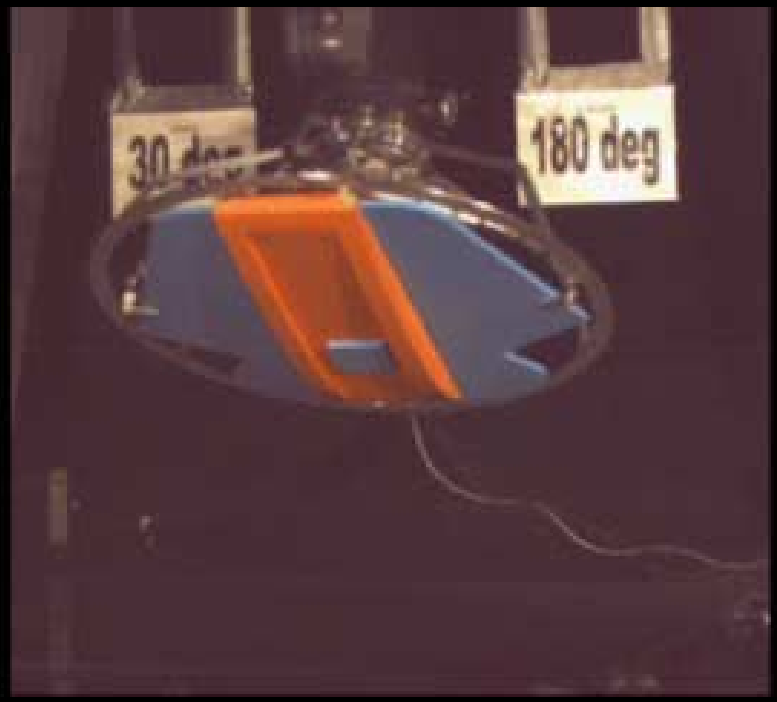
Extraction Simulations

Wind Tunnel Testing

Flight Testing

Airplane Unfolding

Extraction Testing



Airplane Extraction Testing

High Altitude Drop Testing

Tail Deploy

High Altitude Deployment Test,
Sept. 19, 2002
103,000 feet

Left Wing
Deploy

Right Wing
Deploy

Deployments
Complete

Configuration Evolution

Operational Success

Flying Qualities

Tail Unfolding

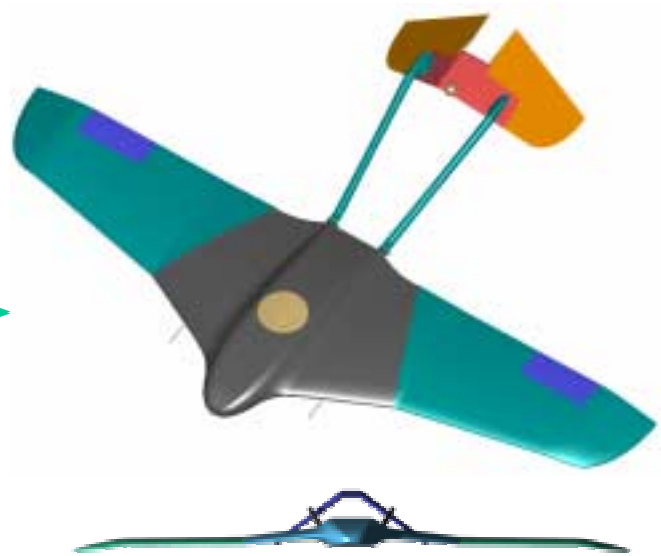
Aerodynamic Tool Validation

Large Equipment Bay

Wing Hinging

Aeroshell

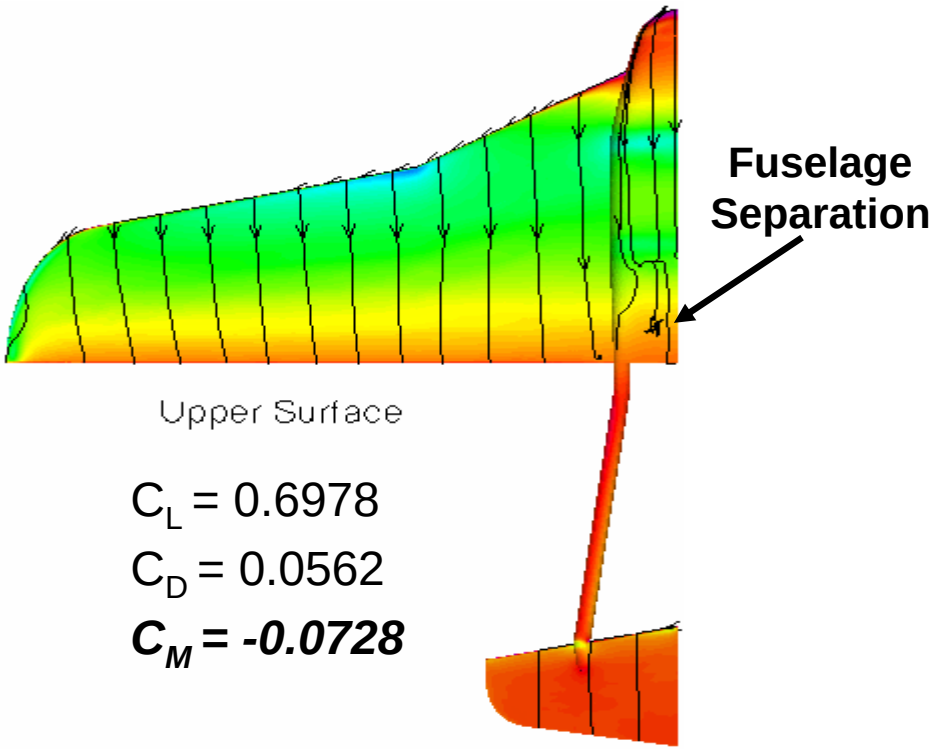
Mission Design Maturation



Design Iteration

USM3D Solutions (M=0.55, Re =103,000 per meter)

ARES - 1

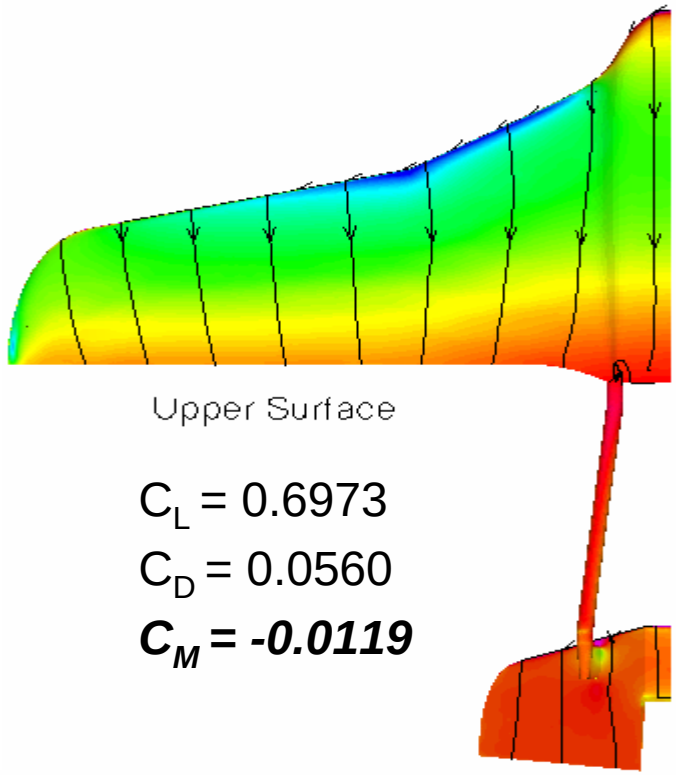


$C_L = 0.6978$

$C_D = 0.0562$

$C_M = -0.0728$

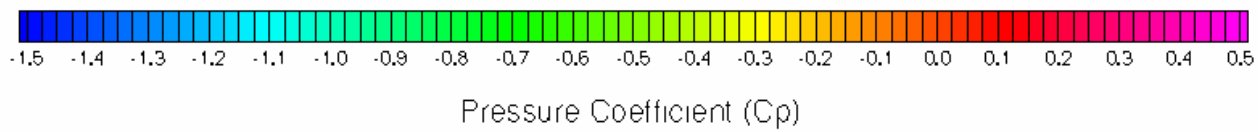
ARES - 2



$C_L = 0.6973$

$C_D = 0.0560$

$C_M = -0.0119$

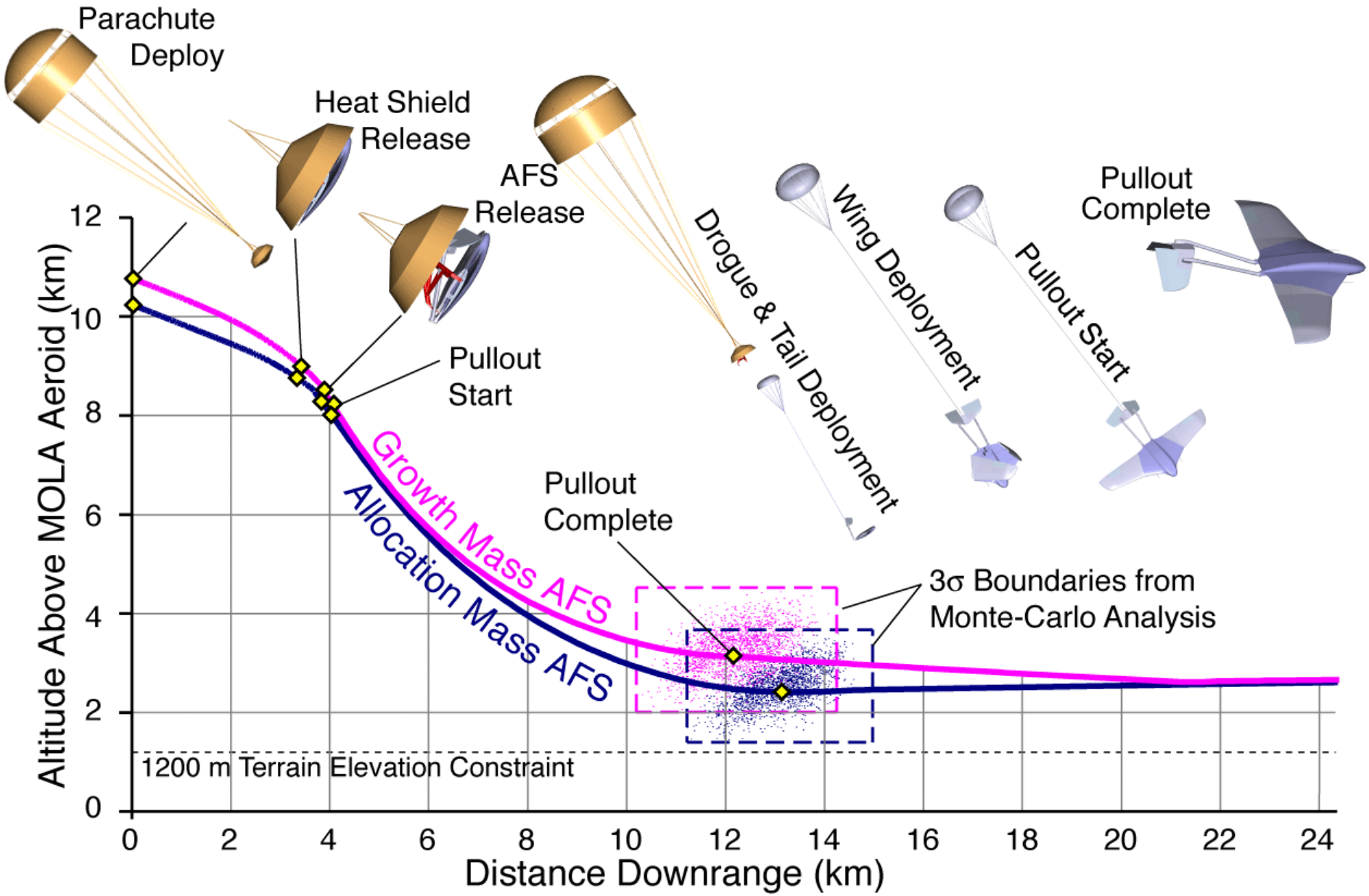


Higher trimmed L/D provided by ARES-2 design

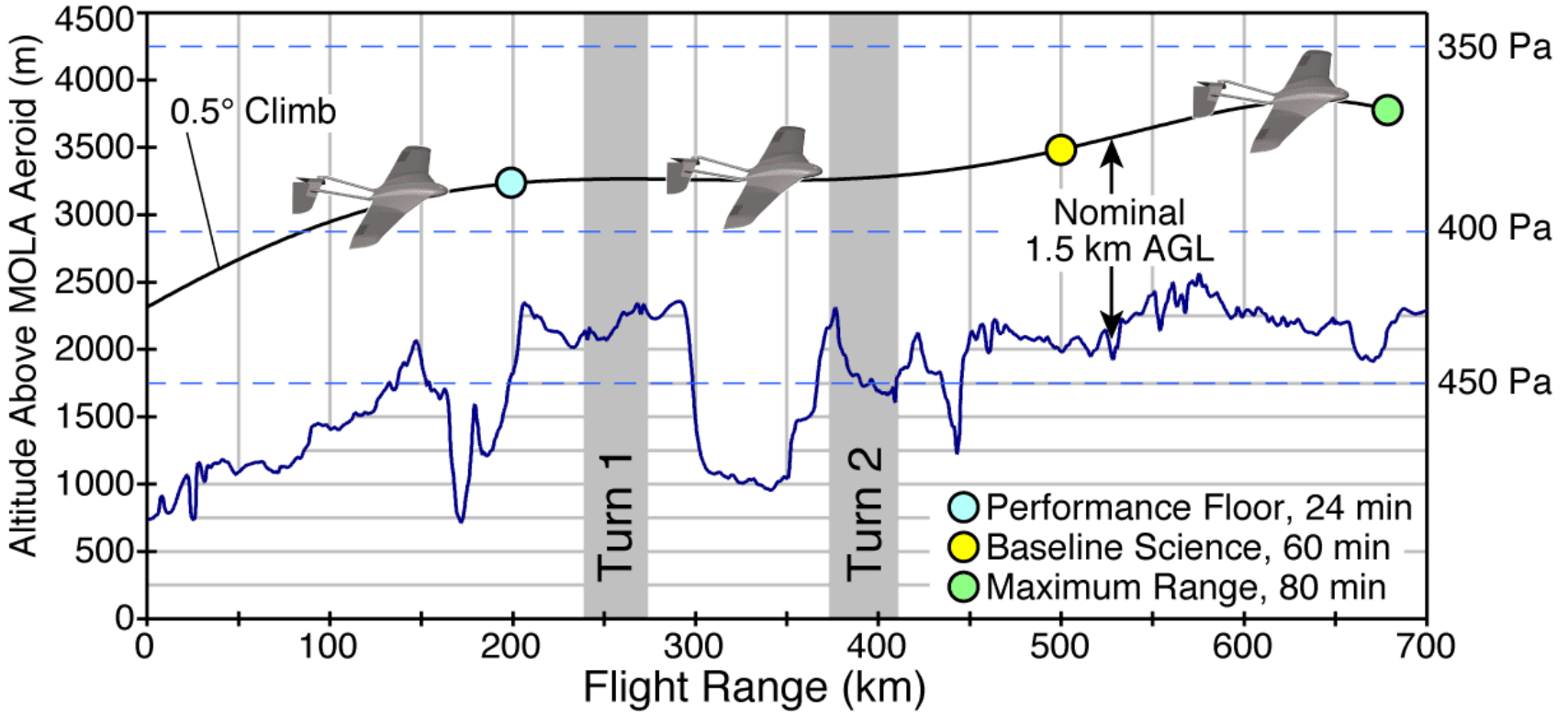
ARES-2 12-Foot & TDT tests

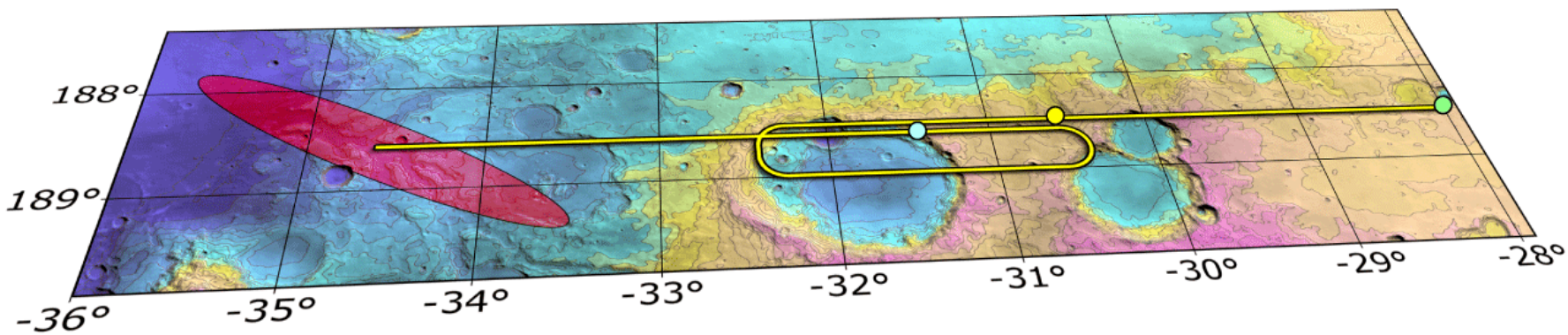
- Static F+M w/ 25%-scale model
- Matching M, Rn
- Low-speed 12-Ft
  - Tail booms, wings folded
  - Large angles (α, β, δ)
  - Extensive S&C
  - Flow visualization
  - ADS, trips, components, chute, etc.
- Transonic Dynamics Tunnel
  - Mach effects
  - Perf, S&C across expected flight envelop (α, β, M, Rn, δ) + margin
  - Used 12-Ft to guide TDT
- Results generally agree with predictions

Deployment and Pullout



Pre-Planned Scientific Survey





Conclusions

- 2007 Mars Scout Opportunity
  - Office of Space Science selected Phoenix proposal
  - ARES received several “Major Strengths”
- Mars / planetary airplane efforts continue
  - ARES was strongly encouraged to resubmit
  - Addressing issues raised during OSS review in Planetary Airplane Risk Reduction Program (PARR)
  - Pursuing other related technology development
- Near-term activities
  - Publications
  - 2D airfoil W-T tests
  - Full scale flight test
  - GN&C maturation